

Self Compacting Concrete – a structural material of high efficiency

Ciprian Asăvoaie¹ and Sergiu Călin¹

¹ Department of Concrete, Materials, Technology and Management, „Gheorghe Asachi” Technical University, Iasi, 700050, Romania

Summary

Increased productivity and improved working environment have had high priority in the development of concrete construction over the last decade.

Because of the different mix design in comparison with traditional concrete and the absence of vibration, different durability characteristics might be expected for self-compacting concrete.

The durability of a cementations material is greatly influenced by the permeability of the material for potentially aggressive substances. As the pore structure of self compacting concrete (SCC) might be different in comparison with traditional concrete some changes in durability behavior may occur.

Additionally, the technology is improving performance in terms of hardened material properties like surface quality, strength and durability.

The productivity is drastically improved through elimination of vibration compaction and process reorganization.

The working environment is significantly enhanced through avoidance of vibration induced damages, reduced noise and improved safety.

KEYWORDS: self compacted concrete, workability, chemical admixtures, superplasticizer.



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1. INTRODUCTION

The need of gaining serviceable concrete able to fill thoroughly the forms that are cast into, without any compacting means was solved by using liquefying additives and super liquefying additives. However, fluid concrete comes with the possibility of segregation.

Obtaining of self-compacting concrete (SCC) states as a new discovery, the concrete with good flowability that does not segregate nor oozes. Self-compacting concrete is a concrete with well-defined composition that in a fresh state flows under its own weight, fills up the formwork, regardless of the shape, and reaches the maximum compacting factor without any need of vibration, with any configuration of the reinforcement in that section.

The flowability and the resistance to segregation of self-compacting concrete, gives it a higher homogeneity, given that the air within the poured concrete is minimum. The self-compacting concrete is frequently made with a low water/cement ratio ensuring a quick hardening and a potential higher resistance.

The concept of the self-compacting concrete was introduced in the branch terminology of concrete industry in 1986 by Japanese professor H. Okamura, being considered the most revolutionary discovery in the past 50 years. The team led by Japanese researcher K. Ozawa was the first to produce self-compacting concrete as a prototype in 1988, with remarkable results in the field of high resistance concrete, for which the manufacturing and casting in place requirements are more rigorous than those for regular concrete. Nowadays, in Japan, the precast industry is orientated towards producing of SCC as everyday usage.

Using of SCC in monolith and precast structures has extended all over the world. In the United States, a recent statistic made by National Precast Concrete Association reveals the fact that 80-100% of the precast manufacturers, members of the above mentioned association, use SCC on everyday basis, having at least one technological line of production for this type of concrete.

Among the European states that systematically implemented SCC technology on a larger types of applications, Sweden, Denmark, Holland, Germany, Spain are to be mentioned.



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Fig. 1 - Using self-compacting concrete in the precast industry

In the same time, in these countries have been elaborated and applied vast researching and experimenting programs considering that by improving the production technology of SCC, in the future 10-15 years, important technical and economic advantages will be achieved.

Self-compacting concrete is also competitive from the price point of view, due to lower price for casting in place of the concrete that balance the more expensive materials that are part of the compound such as: superfine silica or polycarboxylic superplasticizer additive.

These features are shown by reducing labor cost, by shortening the manufacturing time, by eliminating the risks given by noise and vibrations, by simplifying the casting in place process and improving of quality.

In fact, the cost of the staple of the SCC is higher with approximately 13-30% than the cost of the regular mixes with similar properties. In spite if this, the cost analyze reveals that although the selling price of the SCC is a few percent higher, due to the less working labor and the less time needed for construction, the profitability is raised with approximately 10%.

2. ELEMENTS REGARDIND SCC TECHNOLOGY

2.1. Basic aspects

Designing and manufacturing of SCC involves a number of difficulties, regarding a few characteristics that are, by their nature, in contradiction, such as: the need of a good flowability and the segregation, features that depend on the staples used as follows:

- the mixture need to be made with a good flowability and dense enough to avoid segregation and loss of homogeneity;



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- the good flowability of the concrete is obtained using a high dosage by using competitive superplasticizer (with a higher capacity of water reduction at a workability of at least 30-32%). But, attention! Using superplasticizer in excess causes segregation;
- segregation can be controlled by using small aggregates in a higher dosage and sliminess agents, but in these cases attention is required because by obtaining a higher segregation resistance causes loss of a flowability decreased performance in self-compacting process of the SCC. This is why with an optimum ratio of flowability-no segregation issue causes problems especially on site where the amount of small and very small aggregates may vary during a working day. Of course, some important technical-economic aspects may appear in this case on designing and manufacturing of SCC constructions among which we enumerate:
 - a higher dosage of super liquefying material comes with an extra price;
 - viscosity agents have even higher prices than superliquefying and determine, based on arguments shown above, greater efforts in order to establish superliquefying additive/viscosity agent ratio;
 - increasing the cement dosage over certain limits comes with higher prices, increasing of the heating developed during the beginning of the hardening of the SCC and the possibility of cracking more or less emphasized due to the efforts given by the internal stresses that can overcome the tension strength of SCC on a fresh state. That is why SCC of C20/25 class there are usually used cements with binary or ternary composition and mineral powder additives in small grains such as limestone granular dust. That is because the pH should be between 10 and 12 in fresh concrete, to ensure reinforcement protection;
 - for SCC of C20/25 class, there are usually used binary cements (ex.: cement II/A-S; II/A-V; II/B-M) mineral powder additives in small grains either Portland cement CEM I type and mineral powder additives in small grains such as fly ash from thermo-electrical plants, limestone granular dust, other mineral powder with small grains and where superfine silica. But attention, according to SREN206-1, the fly dust additive in a concrete made with type I cement, cannot exceed 33% of the cement mass;

The relative proportions of the key components of the SCC must be in between the limits recommended by The European Guidelines for Self Compacting Concrete as shown below:

- the content of small grain in mass should be 380-600 kg/m³;
- the content in paste (small grain and water) should be 300-380 l/m³;
- the content of water should be 150-210 l/m³;
- the content in volume of 3-7, 7-16 aggregate should represent, in mass, 750-1000kg/m³, respectively, in volume, 270-360 l/m³;
- the content of sand should represent 48-55% from the total mass of the aggregates;



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- water/small grain ratio in volume should be in between 0.85-1.10.

Super liquefiers or additives represent the essential component of SCC. Their existence and availability have revolutionized the use of concrete, creating the possibility of pouring in an easier manner in places and conditions inaccessible before.

The liquefiers and super liquefiers are, in fact, large water inhibitor additives according to ASTM. 1017, that being the reason for which are classified separated.

The main active components of these additives are tensoactive substances. These substances are absorbed by cement particles that give them negative superficial load that determines the rejection activating the deflocculating phenomenon through which is obtained the stabilization of spreading them and rejecting of the air bubbles that cannot attach the cement particles anymore. Because the deflocculating phenomenon blocks a part of the water of the mix and moreover the contact surface between cement particles do not participate at late hydration, the water inhibitor additives determine increasing the surface of the cement that participate to initial hydration and moreover increase the available water content for hydration reactions.

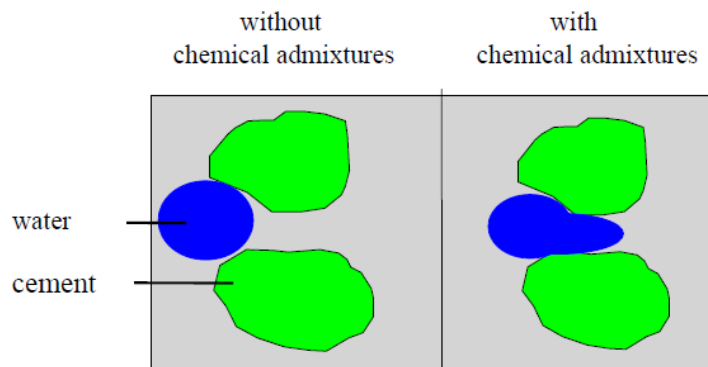


Fig. 2 - The action of the fluidization agents

Superliquefyers are organic polymers water soluble. They are obtained in complex polymerization processes with the goal of giving long chains of large molecular mass. Being fabricated for a certain purpose, their characteristics regarding the length of the chain and a reduced reticular degree can be optimized.

The most of the superliquefyers are presented in a form of sodium salts, but there are also produced calcium salts that are less soluble. A consequence of sodium salts is the fact that they introduce supplementary alkaline in concrete, fact that can be harmful for cement hydration and can ease a possible alkaline-aggregate reaction.



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For this reason, the content of sodium in the additive must be known. In some countries like Germany, for example, this is restricted to maximum 0.02% sodium – cement, this, however, favors retaining the electrostatic load on the surface of the cement. The main action of long molecules consists in wrapping them around the cement particles, giving them a large negative load so as they reject each other. This determines deflocculating and spreading of the cement particles. For SCC is necessary that among superplasticizers other additive for modifying the viscosity should be added to avoid the risks of segregation and to guarantee the homogeneity of the mix even in the case of the high flowability degree.

The deflocculating activity is ensured by a superplasticizers additive can be used in a favorable manner in three ways:

- in order to reduce the quantity of water toward the no additive concrete, maintaining the same degree of workability, is acquired the increase of mechanical strength, the decreasing of permeability and the increasing of concrete durability;
- to increase the workability towards the no additive concrete maintaining the water/cement ratio;
- to reduce the water quantity and the cement quantity so the water/cement ratio maintains unmodified and the workability is the same as the one of the no additive concrete.

Expanding the usage of additives are justified by the fact that the concrete obtained in this manner recommend technical and economical outstanding advantages comparing to the no additive concrete, even though not always at a low price, do not require necessary supplementary expenses because not using them can determine certain economies, for example, in the price of the necessary energy for compacting, in the cement content form the concrete or through increasing the durability of the concrete without any extra safety measures.

It should be said that using rationally the additives increase the quality of the material, they cannot represent a remedies for the weak quality of the main components of the concrete caused by the dosage faults or during the operations of transportation and casting in place.

2.2. The characteristics on fresh SCC. Methods of testing

Because SCC is not to be compacted (by definition), the behavior of the fresh concrete will determine the quality of the casting in place. The ways of testing of the fresh concrete's properties have developed continuously without reaching a general standardization. The main characteristics that fresh SCC must have are:

- the ability of spreading, meaning the property of filling the formwork thoroughly in which is poured;



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- the ability of passing through, that represents the property of the mix of penetrating between the reinforcements, even in the areas crowded with reinforcements without producing the separation of the ingredients or blocking them;
- the segregation resistance that means feature of the mix of maintaining the larger parts suspended, to keep the homogeneity character of the material;

Displaying in quantity terms of these features is difficult because their mentioned values depend in a decisive manner of the type of the application. In the following table there are indicated the used common ranges. (Tab. 1)

There have been suggested many methods for evaluating of the characteristics of the “freshness”. Even though, neither of these methods have not been standardized is to be appreciated that some of these tests will be adopted as standardized testing method without major modifications. Following there are presented, shortly, few of the testing methods of SCC.

Table.1 Conformity criteria for the properties of SCC

No.	The characteristic	The determination	Measurement unit	Current value range	
				Min	Max
1.	Flowing/ filling capacity	Total settlement with Abrams cone	mm	650	800
		“V” funnel	sec	6	12
		Time T50 coresp. to 500mm flowing	sec	2	5
2.	Passing through capacity	“L” box	-	0,8	1
		“J” ring	mm	0	10
3.	Segregation resistance	“V” funnel at 5 min.	sec	0	3

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The cone settling method (flowing test) is, probably, the most spread method for determining the capacity of free flowing of the mix



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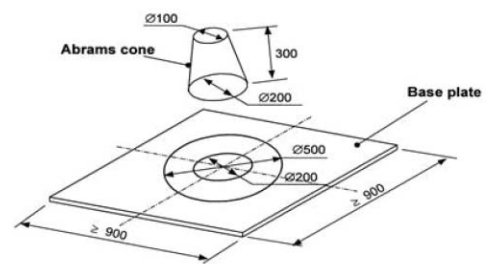


Fig. 3 - The flowing test, made with cone and a non-absorbing plate

This is the best correlated with the flowing tension of the concrete and represents a using tool for analyzing of the consistency of successive determinations. A standard regular cone is placed vertically on a rigid, smooth plate. Afterwards the cone is filled with SCC without compacting it. The cone is vertically lifted to permit the flowing of the concrete. The timer is started and it is recorded the time elapsed until the concrete reaches the shape of a circle with a diameter of 50cm.

The diameter of the settled concrete mass is a proof the capacity of filling of the SCC. The greater the settlement is, the greater the capacity of the SCC to fill the formwork under its own weight is.

Determining the settlement is the most used test, being recommended even on the site because it allows a correct evaluation of the filling capacity and can offer indications referring to the segregation tendency.

Funnel test is used to determine the filling capacity (flowing) of the concrete realized with aggregates of maximum diameter of 20mm. The long time of flowing can be associated with a small deformability due to the large viscosity of the paste and friction between particles.

In order to perform the test it is needed a quantity of 12liters of concrete. The funnel is placed on a rigid platform, moistening the interior surface of the funnel and the shutter is left opened to allow the extra amount of water to flow. The shutter is closed and a bucket is placed underneath it after the funnel is completely filled with concrete without any compacting or hitting. After approximately 10 seconds after filling, the shutter is opened to permit the concrete to flow under its own weight. When opening the shutter, the timer is started and the elapsed time is counted until the funnel in empty. The funnel in considered to be empty when at the base of the funnel appears the light.



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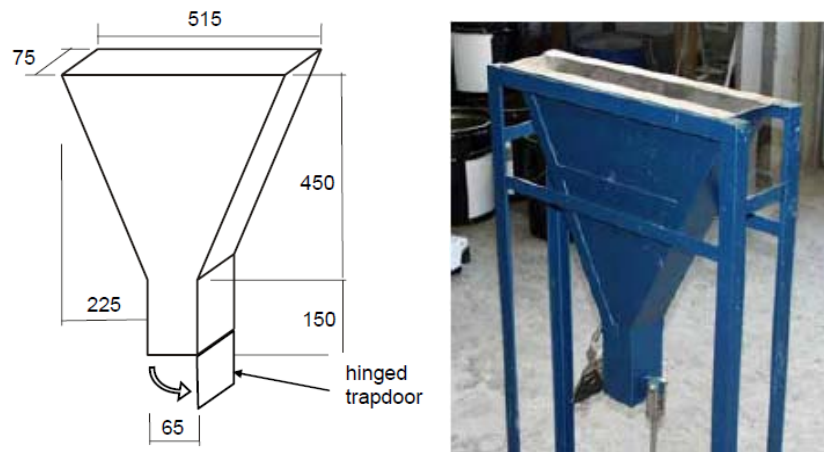


Fig. 4 - V funnel for determining of the flowing capacity and the resistance to segregation

This represents the time elapsed with V funnel and the allowable values are between 6 and 12 seconds.

The "L" box test (the determination of the capacity of flowing an passing through)

It is frequently used in laboratory but it can be used on site also to evaluate the capacity of flowing and passing through, and for visual observation of the tendency of segregation. As the blocking ratio is closer to the unit the greater is the capacity of flowing.

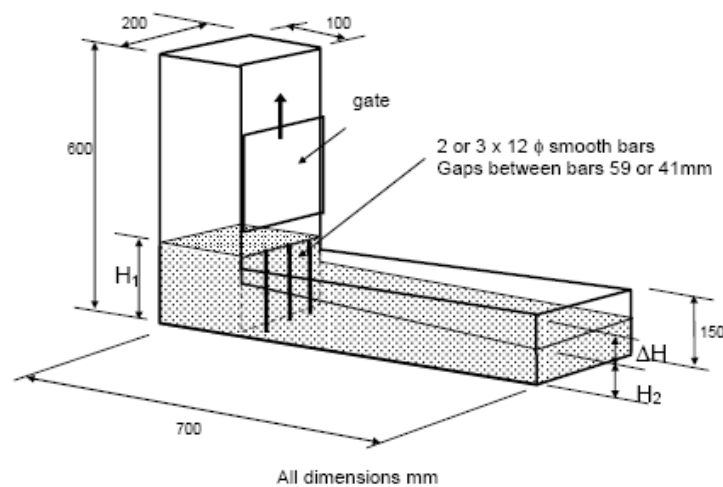


Fig. 5 - L-box



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The level of the concrete is measured at both ends of the box and the value of the ratio H_2/H_1 is a proof of concrete workability 0.8 (0.6-0.85) being the recommended value for SCC. The times T20 and T40 give some indications of the smoothness of the flowing but there are no general accepted recommendable values for these characteristics.

The blocking of the larger aggregates by the reinforcement can be visually detected.

2.3. The hardened SCC characteristics

2.3.1. The compression strength

It is discovered for a long time by Ferret and Abrams that the porosity of the cements as it is manifested in the initial content of the water and air in the mix it is directly connected to the compression strength. The compression strength of self-compacting concrete is slight superior to the compression strength of the regular concrete made with the water/cement ratio as a result to the improving of the adherence between the aggregates and the hardened paste.

2.3.2. The tension strength

The tension strength of SCC of a certain class and age can be in broad way considered to be equal with the one of the regular concrete because the volume of the paste does not influence the tension strength.

2.3.3. The elasticity modulus

Having as a base the two types of composites materials we may say that because the modulus of elasticity of the regular aggregates is greater than the one of the paste and because the absolute volume of the SCC paste is greater than the one of the regular concrete we can expect that the elasticity modulus of SCC to be smaller than the one of the regular concrete, having the compression strengths comparable. Indeed, the most of the datum presented in the specialty literature show that the modulus of elasticity of SCC is smaller than the reference one for regular concretes.

2.3.4. The slow flowing and contraction

Until now, researches regarding S.C.C. creeping are restricted. The creeping occurs in the cement paste and it is influenced by porosity, value that is given by

water/cement ratio of the concrete. During hydration, the porosity of the cement paste and the slow flowing are increased, slow flowing for SCC is larger than the one of the regular concrete having the same strength class.



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The shrinkage is composed by autogenous shrinkage spent during the cement hydration in contact with the surrounding atmosphere. The drying shrinkage is influenced in inversed ratio by the following aspects: the volume of the aggregates, the value of the elasticity modulus of the aggregates and the maximum diameter of the aggregates. For SCC (made with a low water/cement ratio), the shrinkage at drying is, usually, lower than the autogenous shrinkage. The experimental researches shown that, comparing to the reference concrete, SCC has the same rheological deformation, formed by a reduced deformation and an increased slow-flowing.

2.3.5. The adherence to the reinforcement

The regular concrete adherence can be deficient in the case of segregation or in the case when the concrete encloses the reinforcement without achieving full contact with it. The flowability and the cohesion of SCC fights these affects speccially in the case of the bars form the top part of the sections with large heights.

2.3.6. Fire resistance

The fire resistance of the SCC is similar to the regular concrete because SCC can easily reach the requirements for high strength concrete with low permeability.

2.3.7. Durability

The durability of a concrete structure is connected to the surface layer permeability that has to limit the penetrating of the harmful substances, such as: carbon dioxide, sulphates, oxygen and water, into the concrete. Practically, the durability of the concrete depends on the composition of the concrete, the way of casting in place, compacting, finishing, and treatment. The lack of compacting at the surface of the regular concrete, because of the difficulties on vibrating process in narrow places and with dense reinforcement in section can represent a cause for low durability of the regular concrete elements exposed in aggressive environments.

The permeability of the self-compacting concrete depends greatly on the materials that compose the concrete and the water/cement ratio or water/additive ratio, but the self-compacting concrete, unlike the regular vibrated concrete has a low uniform permeability, with no vulnerability areas to environmental agents, fact that gives it a higher durability.

3. CONCLUSIONS

Taking into account the advantages of using SCC: low executions time, assuring the compatibility of the structure in areas where the compacting process is difficult



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to execute, the clean concrete surface, the elimination of the noise during vibration (for precast plants) but, especially the spectacular concrete applications: underwater poured concrete, tunnels, dams, steel columns filled with concrete, etc., it is considered that their studying, the improving of the quality, of the settlement methods, standardizing them and reducing of the costs are important issues for future researches.

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